Realization of Large Footprint Multilayer High Temperature Capacitors Incorporating Novel Dielectric Materials and Rapid Thermal Spray Deposition Routes

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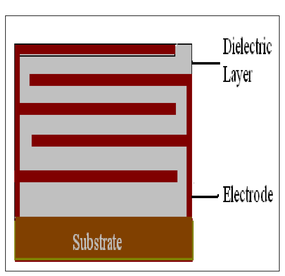
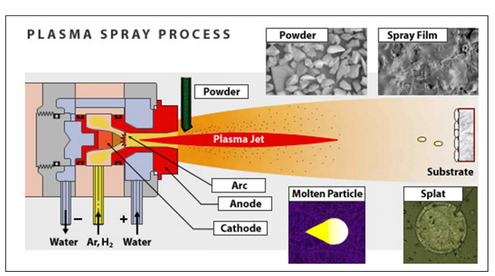
Objective

- High temperature, high power capacitors will improve the performance of existing and future power conversion and energy storage systems by reducing volume and increasing reliability of ceramic capacitors.
- Novel approaches to prepare thick films are especially beneficial for high temperature, high field dialectics to improve long-term capacitor reliability.
- Wide bandgap dielectrics are well suited for higher temperature operations due to lower leakage current and high breakdown strength.
- Understanding through experiments and modeling of electro-thermo-mechanical interactions in multilayer capacitors will provide guidance in designing robust energy storage systems.

Methodology

- Spray coating processes is explored as alternative to tape casting in preparing high temperature multilayer capacitors.
- High melting temperature, wide bandgap dielectrics of intermediate thickness are well suited to the strength of spray coating fabrication.
- Spray coating can be used to deposit both metals and dielectrics enabling scalability for high volume cost effective production with fast deposition times without binder removal and a final firing. step.





Proposed multilayer structure and spray coating process.

Highlights of Phase I

- Successfully proved the concept of multilayer coating of capacitors.
- Single layer and Multilayer capacitors of (a) Al_2O_3/Cu and (b) $BaTiO_3$/ Cu (c) Al_2O_3-TiO_2/Al and (d) Al_2O_3/Al were fabricated.
- Al_2O_3 depositions with added glass and with modified feed nozzles during thermal spray plasma reduced roughness, lowered dielectric losses and resulted in higher breakdown strength of the dielectric layers.
- Laser sintering has further improved the surface texture and morphology of the plasma spray deposited Alumina layers.

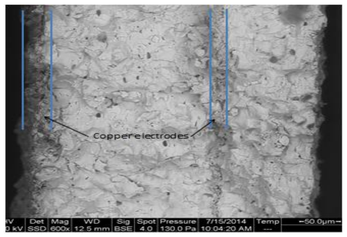
$BaTiO_3$/Cu Multilayer Coating

Al_2O_3/Cu Multilayer Coating

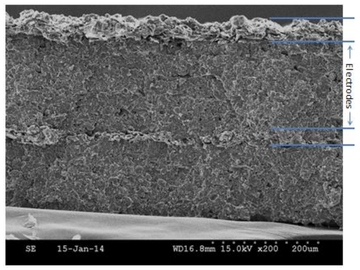
Al_2O_3+TiO_2/Al coating

Al_2O_3/Al coating

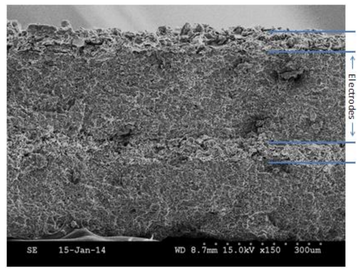
Different multilayer coatings, viz. $BaTiO_3$/Cu, Al_2O_3/Cu, Al_2O_3+TiO_2/Al and Al_2O_3/Al were carried out. The oxide ceramic layer thickness was kept between 0.002”-0.003”, whereas the metal layer thickness was maintained at 0.001”-0.002”. Four such alternating layers were deposited. The Al electrodes show good sheet electrical conductivity ~ 0.04 ohms/square. The coating structure physical properties were analyzed for their overall dielectric strength, loss tangent and polarization.



$BaTiO_3$ / Cu Multilayer



Al_2O_3-TiO_2 / Al Multilayer



Al_2O_3 / Al Multilayer

Proposed work for Phase II

- Selection of Dielectric Oxide Materials and Particle Distribution Design for Deposition Method.
- Through Optimized Thermal Spray Processing of the Dielectric Layers, Improve Density, Smoothness and Dielectric Properties using laser processing route.
- Consider Intermediate Processing Steps to Aid Electrode Densification and Minimizing Flaws.
- Optimize Patterning and Automate the Masking Process to Enable Electrode Patterning.
- Test Electrical Characteristics of dielectrics such as Dielectric Permittivity, Resistivity, Breakdown Strength and Degradation Resistance.
- Microstructural and Chemical Characterization to obtain Process and Device Performance.
- Model Electro-thermo-mechanical interactions in Multilayer Structures.

Acknowledgments

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